

Paper Title: Human Exploration Spacecraft Testbed for Integration and Advancement (HESTIA)

The proposed paper will cover ongoing effort named HESTIA (Human Exploration Spacecraft Testbed for Integration and Advancement), led at the National Aeronautics and Space Administration (NASA) Johnson Space Center (JSC) to promote a cross-subsystem approach to developing Mars-enabling technologies with the ultimate goal of integrated system optimization. HESTIA also aims to develop the infrastructure required to rapidly test these highly integrated systems at a low cost. The initial focus is on the common fluids architecture required to enable human exploration of Mars, specifically between life support and in-situ resource utilization (ISRU) subsystems. An overview of the advancements in both integrated technologies, in infrastructure, in simulation, and in modeling capabilities will be presented, as well as the results and findings of integrated testing.

Due to the enormous mass gear-ratio required for human exploration beyond low-earth orbit, (for every 1 kg of payload landed on Mars, 226 kg will be required on Earth), minimization of surface hardware and commodities is paramount. Hardware requirements can be minimized by reduction of equipment performing similar functions though for different subsystems. If hardware could be developed which meets the requirements of both life support and ISRU it could result in the reduction of primary hardware and/or reduction in spares. Minimization of commodities to the surface of Mars can be achieved through the creation of higher efficiency systems producing little to no undesired waste, such as a closed-loop life support subsystem. Where complete efficiency is impossible or impractical, makeup commodities could be manufactured via ISRU.

Although, utilization of ISRU products (oxygen and water) for crew consumption holds great promise of reducing demands on life support hardware, there exist concerns as to the purity and transportation of commodities. To date, ISRU has been focused on production rates and purities for propulsion needs. The meshing of requirements between all potential users, producers, and cleaners of oxygen and water is crucial to guiding the development of technologies which will be used to perform these functions.

Various new capabilities are being developed as part of HESTIA, which will enable the integrated testing of these technologies. This includes the upgrading of a 20' diameter habitat chamber to eventually support long duration (90+ day) human-in-the-loop testing of advanced life support systems. Additionally, a 20' diameter vacuum chamber is being modified to create Mars atmospheric pressures and compositions. This chamber, designated the Mars Environment Chamber (MEC), will eventually be upgraded to include a dusty environment and thermal shroud to simulate conditions on the surface of Mars.

In view that individual technologies will be in geographically diverse locations across NASA facilities and elsewhere in the world, schedule and funding constraints will likely limit the frequency of physical integration. When this is the case, absent subsystems can be either digitally or physically simulated. Using the Integrated Power Avionics and Software (IPAS) environment, HESTIA is able to bring together data from various subsystems in simulated surroundings, insert faults, errors, time delays, etc., and feed data into computer models or physical systems capable of reproducing the output of the absent subsystems for the consumption of a local subsystems. Although imperfect, this capability provides opportunities to test subsystem integration and interactions at a fraction of the cost. When a subsystem technology is too immature for integrated testing, models can be produced using the General-Use Nodal Network Solver (GUNNS) capability to simulate the overall system performance. In

doing so, even technologies not yet on the drawing board can be integrated and overall system performance estimated.

Through the integrated development of technologies, as well as of the infrastructure to rapidly and at a low cost, model, simulate, and test subsystem technologies early in their development, HESTIA is pioneering a new way of developing the future of human space exploration.